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Study of 23 day periodicity of Blazar Mkn501 in 1997

S.Osone[a]

(a) National Institute of Advanced Industrial Science and Technology, 1-1-1 Umezono, Tsukuba, 305-8568, Japan
Presenter: S.Osone (osone@icrr.u-tokyo.ac.jp), jap-osone-S-abs1-og23-poster

In 1997, flux of Blazar Mkn501 increased up to 10 Crab over three months. X-ray satellite *RXTE* All sky monitor (ASM) and two cherenkov detectors HEGRA, Utah seven telescope array (Utah TA) observed this flare simultaneously. Hayashida et al.[1] and Kranich[2] studied periodicity with Utah TA data, with both HEGRA and ASM data respectively, with a Fourier analysis. They suggest a periodicity of 23 day. Here, we restudied a periodicity for these three data sets with a Fourier analysis and obtain chance probability 4.88×10^{-3} for HEGRA data, which is more significant than previous result by order. We also studied a periodicity with another method χ^2 and obtain same periodicity. We suggest a periodicity strongly. We study a stability of a periodicity in order to set a limit on an origin of a periodicity and found instability with a 3.4 sigma significance. Therefore, we suggest an origin of this periodicity is not a multiple black hole system, but a thermal instability of an accretion disk. We also analyze an X-ray energy spectra of *RXTE* PCA and found three physical parameters, magnetic field, beaming factor and gamma factor are related with a periodicity.

1. Introduction

Hayashida et al.[1] studied a periodicity with Utah TA data with a Fourier analysis and suggest two periodicities of 13 day and 23 day. Kranich[2] studied a periodicity 23 day with both ASM and HEGRA data with a Fourier analysis and obtain a chance probability 0.047 for ASM and 0.028 for HEGRA.

However, there are some problems. There is a 1/f noise in a power-frequency diagram, which is well known in Binary and AGN in X-ray band. Hayashida et al.[1] do not consider an effect of a 1/f noise on both an error of a periodicity and a chance probability of a periodicity. Kranich[2] does not consider an effect of 1/f noise on an error of periodicity. He consider an effect of a shot noise instead of a 1/f noise on a chance probability of a periodicity. However, he fitted a raw power spectra with a shot noise model. The raw power spectra has 100 % error because a power follow χ^2 distribution of 2 degree of freedom. He estimate a chance probability of a periodicity with an unreliable fitting parameters.

Here, we reanalyze three data set with a Fourier analysis and estimate a chance probability of a periodicity with a reliable fitting parameters of a 1/f noise. We obtain an error of a periodicity by including an effect of a 1/f noise and found three periodicities with three data sets are same. We also analyze both ASM data and HEGRA data with another timing method χ^2 in order to raise a reliability of periodicity. We check a stability of a periodicity in order to set a limit on an origin of a periodicity. We analyze X-ray energy spectra with *RXTE* PCA in order to set a limit on physical parameters.

2. Timing analysis

We obtain three data sets, ASM and HEGRA and Utah TA by a form of (MJD, rate, error of rate) in 1997. The data spans are MJD 50545-50661 for ASM and HEGRA data, MJD50520-50665 for Utah TA, which are same with previous papers. We use a Fourier method and confirm 23 day periodicity in three data set. We discuss an error of a periodicity at later.

We also studied a periodicity with another method χ^2 for ASM data and HEGRA data. Fourier analysis is

Table 1. The result of a timing analysis for HEGRA, Utah TA and ASM data in 1997 for Mkn501. The error is a 1 sigma statistical error.

	HEGRA	Utah TA	ASM
Fourier analysis (day)	22.5±0.3	23.6±0.3	22.6±0.5
χ^2 method(day)	22.4	—	22.3
A	$0.44\pm0.14 \times 10^{-5}$	$0.22\pm0.09 \times 10^{-5}$	$0.68\pm0.09 \times 10^{-5}$
b	$0.50^{+0.16}_{-0.20}$	$1.54^{+0.43}_{-0.35}$	0.97±0.08
chance probability	4.88×10^{-3}	0.981	0.200

Table 2. The result of a stability for HEGRA data with Fourier analysis. The error is a 1 sigma statistical error.

	MJD50545-50603	MJD 50603-50661
Fourier method (day)	26.2±0.81	20.1±1.0

sensitive to a monochromatic frequency and χ^2 is sensitive to sum of multiple frequency. We make a phase diagram for a period from 1 day to 116 day by 0.5 day and calculate χ^2 for each period. We obtain a periodicity as a maximum peak in a period vs. χ^2. We show period vs. χ^2 diagram as figure 1. We obtain 23 day as a second maximum peak for HEGRA data. We obtain a periodicity 23 day for ASM data. We suggest an existence of 23 day periodicity strongly.

We binned three power spectra in order to raise a reliability of a power and confirm a 1/f noise. We show a binned power spectra for HEGRA data at figure 2(left). We fit a binned power spectra with a power $P = 1 + af^{-b}$. Here, f is a frequency, power P=1 is Poisson statistics. We show fitting parameters at table 1. Instead of a, we use an area A in (10^{-7} Hz, 10^{-5} Hz) because a and b are strongly coupled. The detected periodicity may be a fluctuation of a 1/f noise. Therefore, we have to calculate a chance probability for a detected periodicity with simulation data which show an observed 1/f noise in a power spectra. We show a chance probability at table 1. We obtain a significance 4.88×10^{-3} for detected periodicity for HEGRA data.

We estimate an error of a periodicity with a fluctuation of an observed light curve. We give a standard deviation of an observed data as a fluctuation for a simulation. We analyze simulation data with a Fourier analysis and we obtain an error of a periodicity from a distribution of a periodicity in simulation data as table 1. With a 1.3 sigma error, three periodicities are consistent.

We divide good statistical data HEGRA into two epoch and analyzed with a Fourier analysis. We obtain an error of a periodicity with same way. We show a result at table 2. We found a periodicity is unstable with a 3.4 sigma significance.

3. X-ray energy spectra analysis

We obtain an archive data of PCA for Mkn501 in MJD 50300-50900 and analyze these data according to a RXTE instruction. We make an energy spectra for one continuous observation, about 10 ksec. Total number of an energy spectra is 56. We fitted each energy spectra with an absorbed power law, dN/dE = $e^{-N_{\rm H}\sigma}E^{-\alpha}$. Here, σ is a cross section of a photo absorption, $N_{\rm H}$ = 2.08×10^{20} cm^{-2} and α is a photon index. We make spectral data set by a form of (MJD, photon index, error of photon index). We make a phase diagram of a photon index as figure 2. X-ray emission is considered as a synchrotron emission by SSC model. The index in νF_ν(erg/s)

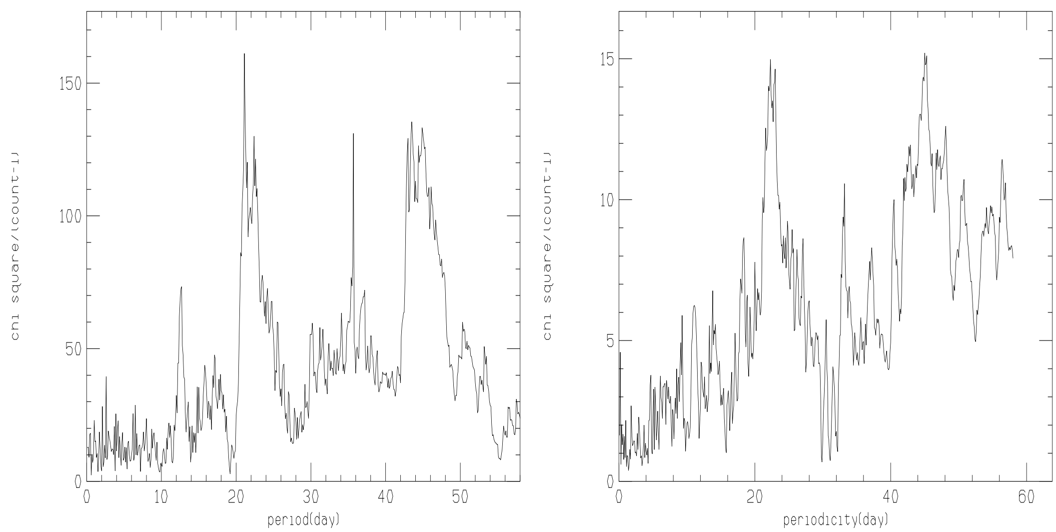

Figure 1. The χ^2 diagram for HEGRA data(left) and ASM data(right)

vs. ν(erg), $-\alpha + 2$, change from -0.2 to 0.4. This means that a peak energy of synchrotron emission change during this flare. The peak energy is written by three physical parameters, a magnetic field, a beaming factor and a gamma factor. Therefore, these three physical parameters are related with a periodicity.

4. Discussion

For Blazar, we see emission from a jet and a time duration in an observer system become shorter than that in a jet system by a beaming effect. The intrinsic periodicity is 1 yr with a typical beaming factor 10. 1 yr. periodicity is not a geometrical origin as a multiple black hole system because a periodicity is unstable. There is instability for AGN itself. For black hole candidate binary GRS1915+105, 10 sec unstable periodicity was found[3][4] and is suggested as thermal instability of an optically thick accretion disk[5]. According to an AGN grand unification, we see a jet activity as Blazar, an activity of an accretion disk as Seyfert1, Seyfert2. Recently, the relation between X-ray emission from an accretion disk and radio or infrared emission from a jet were found[6][7]. Therefore, we may see an activity of an accretion disk through emission from a jet. By scaling a black hole mass from a binary 10 $M_\odot$ to an AGN $10^7 M_\odot$, we obtain 1 yr periodicity. Therefore, we suggest that an origin of 23 day periodicity is thermal instability.

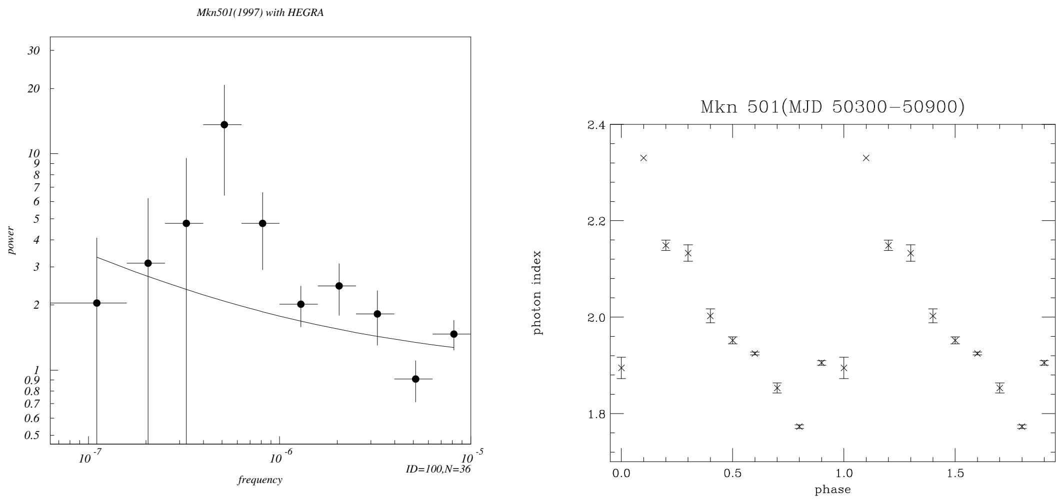

Figure 2. The binned power spectra for HEGRA data. The data point 5×10^{-7} Hz is removed as a periodicity in fitting(left). The phase diagram of photon index in X-ray band(right)

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